Two System Proposal

# Further Notes on the Deployment of Two Cross-Polarized Systems in the ATG Band and Response to Verizon Airfone /Telcordia

## Prepared for

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## Prepared by

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# Further notes on AirCell XP proposal

## 1. Introduction

This document clarifies and elaborates upon certain aspects of the AirCell/Boeing proposal for the use of cross-polarized (XP) signal isolation to allow two competitive carriers to share the ATG band, previously submitted in [1]. The provision of service to aircraft on the ground at airports is addressed in greater detail, recent flight test results measuring cross-polarization isolation are reported, and certain site engineering questions are addressed.

AirCell also takes this opportunity to respond to issues raised by Verizon Airfone in its recent ex parte filings that include a Telcordia review of the cross-polarized ATG band-sharing proposal [2]. Verizon/Telcordia's technical analysis and conclusions are clearly incorrect and/or misleading on a number of significant points:

- The AirCell/Boeing proposal has evolved significantly over the course of this proceeding, a fact that Airfone appears to ignore or not recognize. The inescapable fact is that a carrier using either polarization can provide virtually the same capacity as a single carrier using vertical polarization.
- Cross-polarization has been used extensively to provide isolation between line-of-sight microwave systems for several decades, and AirCell has successfully used cross-polarization to provide isolation between terrestrial cellular services and co-banded ATG services for many years. Cross-polarization is well understood to primarily depend upon the relative orientation of the antennas in a line-of-sight environment. Verizon/Telcordia have yet to present a single realistic scenario in which ATG cross-polarization isolation will be diminished by any other effect. Moreover, Telcordia's analysis of the effects of altitude on cross-polarization is totally incorrect – it misrepresents the effect of using a particular antenna pattern as an altitude effect. We will show that cross-polarization is preserved for all points in space, using antennas meeting the criteria previously suggested by AirCell.
- Contrary to Telcordia's claims, 200 mW is an appropriate transmit power for the airborne mobile. This power level is sufficient to drive the base station receiver to a 75% pole point load from a single aircraft, and no significantly higher power level can provide a significant benefit in terms of data rate throughput.
- Verizon/Telcordia's claim that the two systems would have to be operated in tandem, with a common admission control mechanism, is not justified by any level of analysis. AirCell has outlined system design coordination requirements for two carriers using cross-polarization, and AirCell's analysis has shown that the isolation available will allow such systems to operate with minimal inter-system impacts.

This paper will further confirm that "two parties behaving with enlightened self-interest" can readily implement AirCell's current proposal. The engineering practices required to assure that two carriers can operate in the ATG band, are consistent with the prudent engineering practices that a single carrier would adopt to maintain efficient system operation, and the cross-polarization isolation will allow two carriers to operate within the ATG spectrum with minimal inter-system impacts.

## 2. Deck-to-deck and Gate-to-gate coverage

AirCell's (and Boeing's) initial submissions to the Commission regarding potential competitive spectrum-sharing proposals contemplated provision of air-to-ground (ATG) service for aircraft operating at 10,000 feet and above. Current FAA guidance [3] and common airline practice requires that Portable Electronic Devices be shut off and stowed below this altitude while aircraft are taking off and landing. Communications traffic will therefore be unlikely or minimal when aircraft are below 10,000 feet.

However, as-yet-unforeseen changes to FAA regulations and guidance may eventually increase the amount of traffic generated by arriving and departing aircraft. In addition, aircraft often spend extended periods of time positioned at ramps or on taxiways, where large amounts of traffic may be generated. In [4], AirCell proposed an architecture that allowed multiple carriers to share the ATG spectrum for aircraft in flight, with handoffs to/from terrestrial licensed facilities as aircraft land and take off, and we will elaborate further on that concept in this section.

### 2.1. Terrestrial licensed systems for aircraft on the ground

An ATG service provider wishing to provide service on the ground has multiple options for terrestrial service. A handoff at 200-500 foot altitudes corresponds to a handoff within less than 2 miles of end of the runway. Spectrum coordination requirements for terrestrial channels will be for an area of only a few miles surrounding the airport. The coordination distance will depend on the handover altitude, and, to a lesser extent, the data rates (and related power levels) required to serve the communications needs of the aircraft at the time of handoff.

Handoffs are envisaged as handoffs of the entire communications channel between the aircraft and ground network, rather than a handoff of any individual devices on the aircraft. All active communications devices on board the aircraft will continue to be served by their associated on-board systems. Figure 1 below illustrates a possible configuration for the on-board system, showing a variety of initial and future services that might be provided on the aircraft, with a common "broadband pipe" carrying all traffic from the aircraft. This type of arrangement simplifies aircraft systems management and provides efficient use of aircraft to ground network resources.

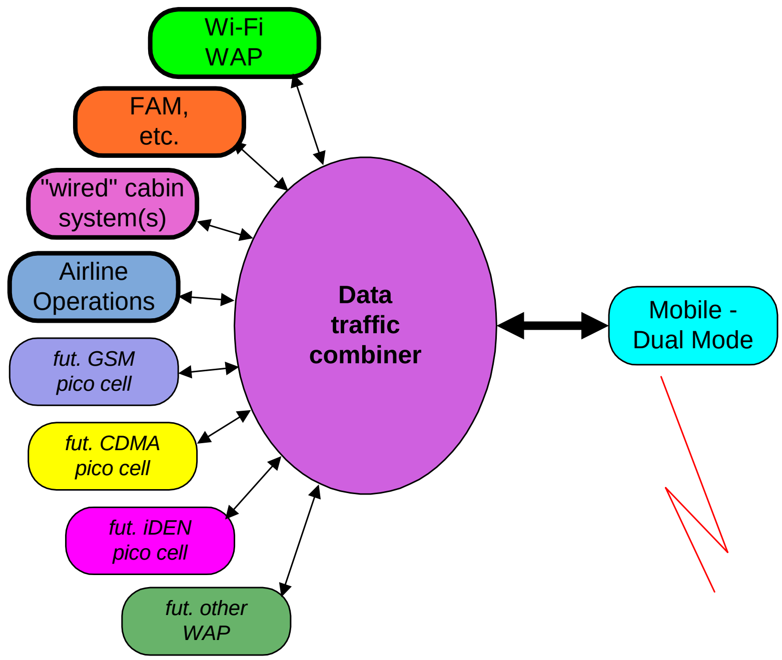


**Figure 1** A possible aircraft system

In this configuration, a dual mode mobile on board the aircraft will be capable of providing service in the ATG licensed band as well as for a terrestrial licensed band. The ground network will include base stations operating in both licensed bands, in a configuration similar to that shown in figure 2 below.

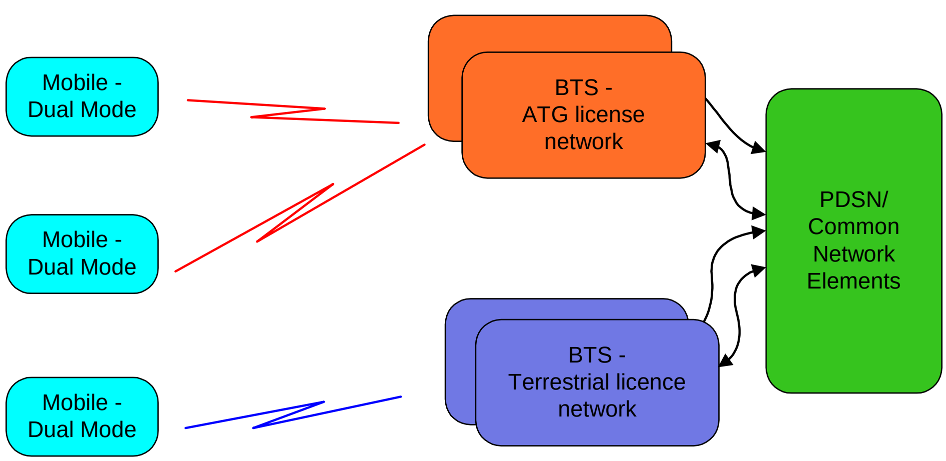


**Figure 2.** ATG and Terrestrial licensed network elements

The BTSs operating on the terrestrial spectrum and those operating on the ATG spectrum will share a common core network. The dual mode mobiles on the aircraft will handoff seamlessly between the two types of base stations, much as mobiles might currently hand off between cellular and PCS bands. A typical airport environment is shown in figure 3 below.

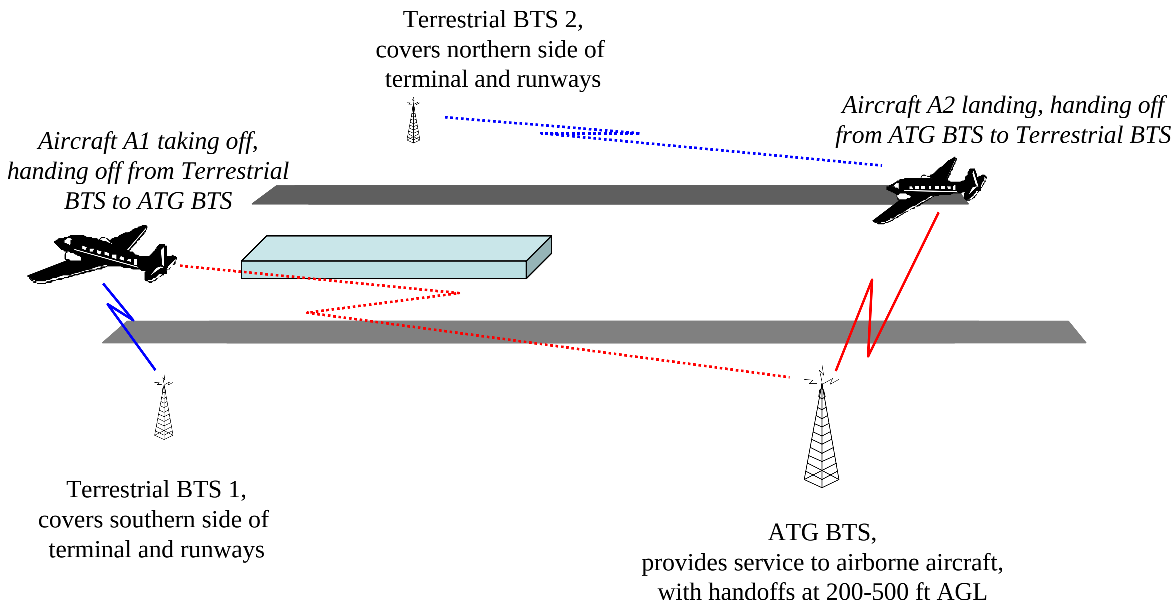


**Figure 3.** Typical airport with ATG and terrestrial license base stations

An airport will typically be served by an ATG-licensed base station that will provide coverage for all aircraft in the vicinity of the airport, to a level of 200-500 feet AGL. Sufficient terrestrial-licensed base stations will provide coverage of all of the gates, taxiways and runways, and offer adequate capacity for the traffic load generated by aircraft on the ground.

Note that candidates for terrestrial licenses are not limited to the cellular and PCS networks, although they may be favored because of the broad similarities in network requirements. Any other suitable spectrum could be used, and, even different common air interfaces could be used, subject to the development or availability of handoff capabilities.

## 2.2. Advantages of dual mode service to aircraft

There are a number of advantages to the use of dual mode mobiles on board the aircraft.

Service to aircraft throughout an airport will generally require multiple cell sites due to coverage issues created by buildings. Large on-ground traffic volumes will also require that additional sites be constructed to support capacity requirements. Terrestrial-licensed base stations can be engineered to meet any on-ground coverage and capacity requirements without impacting in any way the efficient and effective use of scarce ATG spectrum.

Using terrestrial-licensed base stations also clearly allows the ATG spectrum to be used only for line-of-sight service, thereby preserving polarization isolation and supporting the shared use of the ATG spectrum by two competitive carriers.

Moreover, the use of terrestrial-licensed base stations for service to aircraft on the ground minimizes the potential for interference from the ATG band into the adjoining bands shown in figure 4 below.

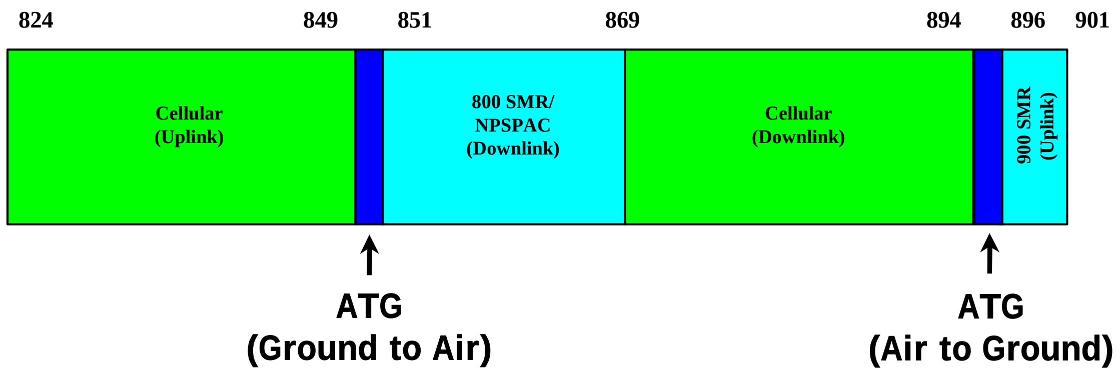


**Figure 4.** Adjoining bands for ATG spectrum

If ATG-licensed base stations are used to provide service to on-ground aircraft rather than terrestrial-licensed base stations, there are several important impacts to the potential for interference between the ATG spectrum and adjoining bands:

- Traffic volumes on ATG spectrum from aircraft at (or very near) the airport will be much higher. Conversely, traffic levels from aircraft handing off to terrestrial-licensed base stations will be very low near the airport, as they will be limited to take off and landings when passenger communications will likely be very low.
- Mobile transmit levels in the ATG band will be much higher due to the use of ATG spectrum in a obstructed, multipath environment. However, transmit levels in the ATG band just at the time of handoff to the terrestrial-licensed base stations will be very low since all such propagation paths will be line-of-sight.
- Without terrestrial handoff, ATG Base station antennas will direct much higher power levels towards the airport terminals in order to provide adequate coverage and capacity. Since ATG-licensed base stations in a two license scenario with handoff do not need to provide such coverage, they will typically operate with uptilted antennas, and will therefore have much lower interference potential for services using adjoining bands in the vicinity of the airport.

AirCell has had discussions with Nextel and APCO to evaluate the impact of deployment of two cross-polarized systems in the ATG band in accordance with the AirCell proposal. The preliminary conclusion of all parties is that the AirCell proposal can be implemented consistent with current inter-band interference guidelines, including those in the recent *800 MHz Report and Order.*

## 3. Site Engineering issues

Commission staff had raised questions regarding the implementation of deck-to-deck service in the vicinity of airports with nearby mountains. Could the nearby mountains create reflections that might cause depolarization of the signals, leading to greater inter-system interference?

AirCell assessed the engineering difficulties that would be related to the terrain in the vicinity of Denver and Salt Lake City airports, as these were two locations mentioned as examples of potential problems.

In order for a reflection to have an impact of the polarization of the received signal, there are two requirements. First, the reflection must cause polarization rotation of the reflected signal, and second, the magnitude of the reflection must be comparable to that of the unobstructed, line-of-sight primary signal. The likelihood of a sufficiently large reflection from the rugged surface of mountains is thought to be very low due to the improbability of reflections from multiple surfaces arriving with a common phase angle. However, a detailed analysis of that likelihood is not necessary to eliminate concerns about the probability of depolarizing reflections from mountains, as will be shown in the following sections.

### 3.1.

### 3.2. Denver airport

The map below as figure 5 shows the Denver International Airport and surrounding terrain.

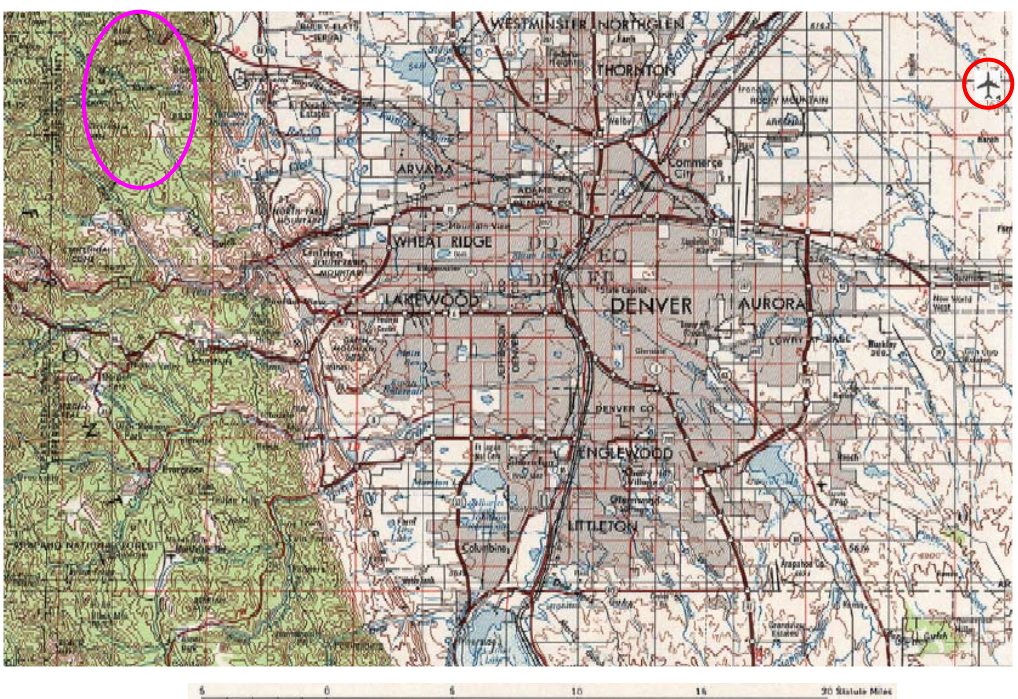


**Figure 5.** Denver International Airport and surrounding terrain.

The Denver airport is located approximately 30 miles east of the mountains. Clearly, any signals reflected from those mountains to an aircraft will be much lower than the LOS signal from a base station located near the airport because of the long paths associated with the reflected path and the low efficiency of the mountain as a passive antenna (or reflector). Further, the tops of those mountains are roughly 1.1° degrees above horizontal. For base station antennas with a very nominal uptilt, the mountain surfaces will be only slightly illuminated, and any reflected signal will be well below the level of that of a direct, line-of-sight path to an aircraft.

In the case of the Denver airport, no special site engineering will be required to deal with mountain reflections.

### 3.3.

### 3.4. Salt Lake City Airport

The Salt Lake City airport is located much closer to the surrounding mountains, as shown in figure 6 below.

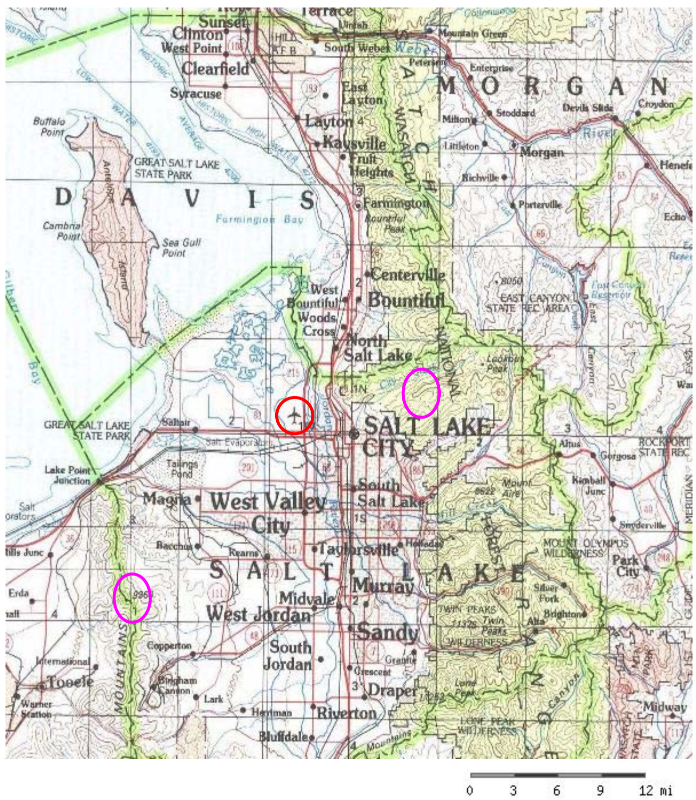


**Figure 6.** Salt Lake City Airport and surrounding terrain.

In the case of the Salt Lake City Airport, the nearest mountains are about 8 miles away and about 3300 feet higher than the airport. The angle to the top of the mountains is therefore 4.5° above horizontal. To the west, the highest peaks are about 3.5 degrees above horizontal. Antennas with slightly greater uptilt than normal would assure that the mountains receive little illumination from the airport base station.

Alternatively, the site could be engineered with directional antennas. Air traffic to the airport is directed through arrival gates roughly 40 miles north and south of the airport. Aircraft approach the airport from these gates traveling along N-S routes, parallel to the mountains. Using directional antennas oriented N-S will provide coverage to all aircraft without providing significant illumination to the mountains. Presuming, for the sake of discussion, that there are significant reflections possible from the mountains, implementing either approach will involve a very modest engineering effort and will eliminate any adverse possible effects.

While these airports represent only a small sample of all airports that will likely be covered with ATG service, they are representative of two of the "worst" cases. AirCell believes that any other airport issues will be resolvable with very modest site-specific engineering efforts.

## 4. AirCell flight tests – cross polarization discrimination

In 1993, GE Corporate Research conducted tests to evaluate cross polarization isolation on air-to-ground paths, and concluded that the isolation was greater than 15 dB [5].

During the week of November 8$^{th}$, 2004, AirCell conducted additional tests at its Wichita Falls site to re-confirm polarization isolation values. These tests showed mean isolation values of more than 18 dB, with 95 percent of the values measured exceeding 11.5 dB. Appendix A contains a description of the test procedures and provides an analysis of the data gathered.

Based upon an understanding of the basic nature of line-of-sight microwave paths, the conclusions reached by GE Corporate Research several years ago based upon the tests they conducted, and the results of the recent AirCell tests, we are confident that the design value of 12 dB of cross-polarization isolation will be readily realizable during implementation of two competitive ATG systems.

## 5. Verizon ex parte – November 3, 2004

On November 3, 2004, Verizon filed an ex parte letter with an attached technical paper [2]. Verizon and Telcordia attempt to make the case that there will be significant interference to ATG systems with two systems operating using cross polarization isolation. Their rationale appears to be a combination of speculation and incorrect analyses, and we address several of the issues raised in the following sections.

### 5.1. The airport scenario and two carrier cross-polarized analysis is new

Telcordia asserts that the proposal analyzed in the 4-system sharing proposal submitted by AirCell [6] is "essentially the same" as the current proposal with respect to cross-polarization isolation implementation. This is not accurate. Furthermore, the comments made by Telcordia with respect to the 4-system proposal were also inaccurate.

The two scenarios differ in several ways, particularly with respect to the airport scenario. The 4-carrier proposal had four, three-sectored sites per system spaced on a 12.5-mile radius circle. The analysis successfully showed the robustness of the isolation mechanisms – each carriers could operate multiple, heavily loaded cells without degradation due to inter-system interference. However, this traffic load was never intended to represent an expected offered load.

In fact, as discussed earlier, it is likely that the offered load on airport sites will be quite light due to restrictions on the use of PEDs for altitudes under 10,000 feet and the handoff of ground based aircraft traffic to a terrestrial network.

In the recent two-carrier analysis, base stations are located near the airport, and are located within 2 miles of each other to minimize near-far impacts. Whereas the 4-carrier analysis was based upon random aircraft positions and altitudes, the 2-carrier analysis was based upon the constraints of the aircraft landing and take-off patterns for a typical airport.

In summary, Telcordia's representation that the two scenarios are "essentially the same" with respect to cross-polarization performance is incorrect and their conclusion that the 2-carrier solution is flawed based upon their analysis of the 4-carrier system solution is unsupportable due to the substantial differences in the two systems. Furthermore, even if this was not the case, their analysis of the performance of the 4-carrier system are incorrect to the extent they are relying upon clearly excessive traffic loads.

In fact, both AirCell/Boeing and Verizon have proposed the use of EVDO broadband systems. In the absence of intersystem interference, each system can be operated at traffic levels that are ultimately governed by the characteristics of that technology and the permitted load as a percentage of the pole point load. AirCell has shown that there are very low levels of inter-system interference with cross-polarization isolation in place – and therefore the performance of each system will be governed by the underlying capabilities of the air interface technology.

## 5.2. Intersystem isolation will be sufficient

Telcordia offers comparisons of other means of isolating systems that operate in the same geographical region – citing in particular out-of-band emission requirements on the order of 40-50 dB between adjacent-band systems.

AirCell's analysis shows that 12 dB isolation is adequate for the ATG band, given the characteristics of the ATG RF environment, the interference tolerance of wideband CDMA signals and the proposed level of coordination between systems. Comparison to a requirement for out-of-band interference levels between two systems that may be of any channel bandwidth and employ any technology, with none of the near-far mitigation measures provided by AirCell, is not relevant.

While AirCell's analysis was based on 12 dB of isolation, this level will be exceeded a large percentage of the time. Typical cross-polarization levels will exceed 15 dB based upon tests conducted by GE Research Labs and AirCell. In addition, an additional 2.2 dB of isolation between systems will be provided once the use of the legacy narrowband system is discontinued and the spectrum occupied shift to a partial overlap rather than a full overlap.

Telcordia's additional speculation that the emission controls of the two cross-polarized systems would need to be coupled is not in any way justified by any analysis or simulations, and is certainly not a requirement under AirCell's proposal.

## 5.3. Polarization isolation can be managed

The polarization orientation of a signal from an antenna is primarily a function of only two factors; antenna construction and the physical orientation of the antenna.

Both are easily evaluated, especially considering the level of precision on polarization orientation is not stringent (12 dB of polarization isolation corresponds to 14.5° of antenna “mis-orientation”).

Telcordia asserts that polarization isolation cannot be readily tested. AirCell agrees that this is indeed difficult – but again, it is irrelevant providing antenna performance and orientation can be monitored.

Telcordia states that polarization isolation in a mobile environment cannot be reliably maintained. The mobile environment is characterized by obstructed paths and high multipath levels. The ATG environment is a line-of-sight environment with very limited secondary signal paths. The mobile environment is very different than the ATG environment, and of no relevance in a discussion of ATG polarization isolation.

## 5.4. Altitude differences do not cause loss of polarization isolation

The analysis presented by Telcordia in the Appendix is lengthy, but totally incorrect in its conclusions. The choice of antennas can cause loss of polarization isolation at altitudes, but polarization isolation is not affected by altitude when appropriate vertical and horizontally polarized antennas are used.

The use of a horizontally mounted electric dipole to generate a horizontally polarized signal is inappropriate and produces the misleading results discussed by Telcordia. If a vertically mounted magnetic dipole is used as the basis for analysis, it becomes clear that cross polarization is maintained between horizontally and vertically polarized antennas throughout all space.

Consider the fields developed by an electric dipole, mounted vertically with respect to the surface of the earth or z=0 plane. Figure 7 below illustrates the fields. The gain pattern of the dipole is also shown – the well-known toroidal pattern, with omnidirectional gain in the horizontal plane and with a deep null directly above and below the dipole in the vertical plane.

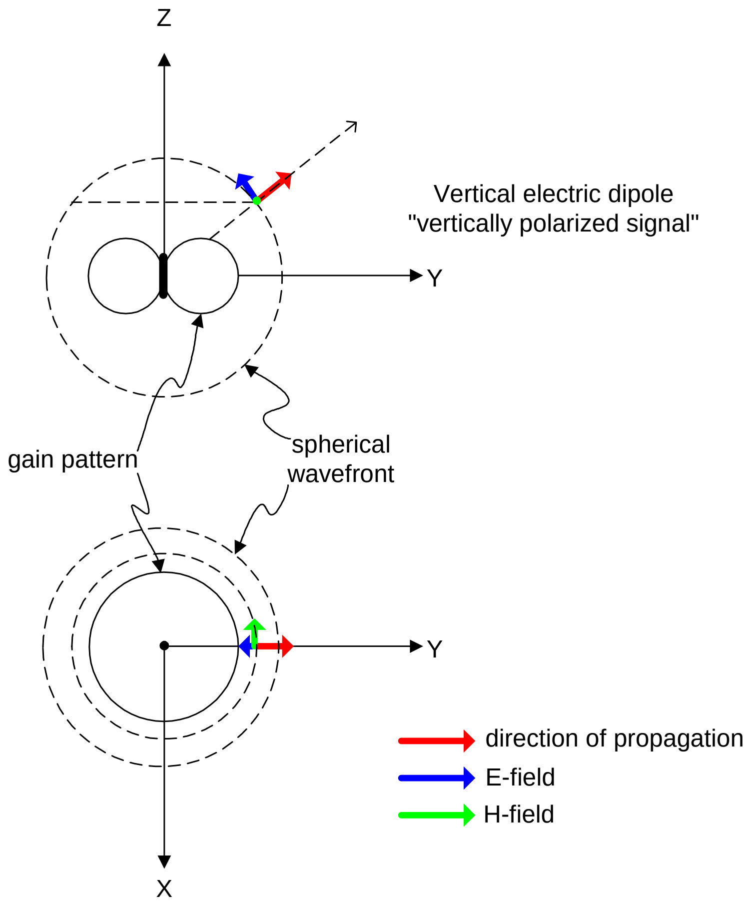


**Figure 7.** E-field and H-field of an electric dipole, mounted vertically

The polarization of an antenna is that of the direction of the E-field. For a vertically mounted electric dipole, such as that shown in figure 7, the E-field is vertical at any point in the z=0 plane. Since both transmitting and receiving locations are usually both mounted on a plane parallel to the surface of the earth, the polarization of a vertically mounted electric dipole is considered to be “vertical” (even though the direction of the electric field is clearly not vertical for points not on the mounting plane).

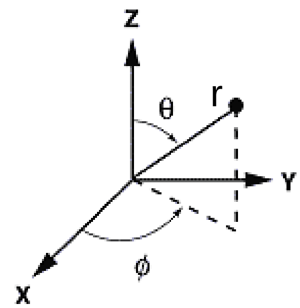


**Figure 8.** Spherical coordinate system

Referenced to a spherical coordinate system such as that shown in figure 8 above, the direction of propagation is $\vec{r}$, the E-field direction is $\vec{\theta}$. and the H-field direction is $\vec{\phi}$. At any given point in space, $(r,\theta,\phi)$, the direction of propagation, the E-field and the H-field will always be mutually orthogonal. This is of course also true, although somewhat less obvious, when a planar coordinate system is used. Even though for any point not on the z=0 plane, all three vectors will have horizontal components, the three vectors will still be orthogonal. Note that the H-field of the vertically mounted electric dipole is always parallel to the z=0 plane.

Consider a situation with two vertically mounted electric dipoles at different altitudes, and consider any point on the propagation path connecting those two dipoles. Consider the wavefront spheres of the two antennas that contain the point being considered. To simplify the analysis consider a vertical plane that passes through the two antennas (and which of course contains the propagation path and the point of interest.) This plane is illustrated in figure 9, below.

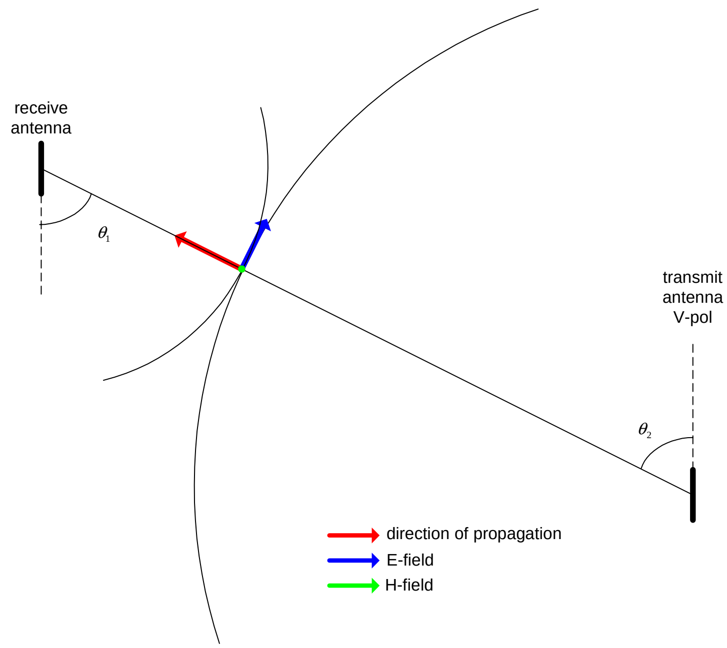


**Figure 9.** Two vertically mounted electrical dipoles antennas

Since both antennas are mounted vertically, $\theta_1 = \theta_2$. Invert one antenna (and its associated coordinate system) and consider the two spherical coordinate systems associated with the two antennas. It is apparent that the H-field will be parallel to the z=0 plane (i.e. perpendicular to the plane containing the two vertical elements) for both coordinate systems. The propagation direction will be at the same angle $\theta$ in both systems since one of the coordinate systems is inverted. Since the direction of propagation, the E-field direction and the H-field direction will be mutually orthogonal in both coordinate systems, it follows that the direction of the E-field must be the same for both coordinate systems, and therefore the polarization of the two antennas must be the same. There will be no polarization mismatch, regardless of the relative separation of the two elements (in x, y, and/or z directions) although the antenna gain will be less than the maximum for $\phi_1 = \phi_2 \neq 90$.

The vertical electric dipole may be considered the basic unit for construction of high gain, vertically polarized antennas, often in co-linear arrays with spacing and phasing of dipole feeds used to provide the desired gain.

The magnetic dipole provides a pattern that is analogous to the electrical dipole, but with the E-field and H-field orientations exchanged as shown in figure 10 below. The gain patterns of a magnetic dipole and an electrical dipole are virtually the same, but the E field is now parallel to the z=0 plane, and the antenna is horizontally polarized with an omnidirectional pattern.

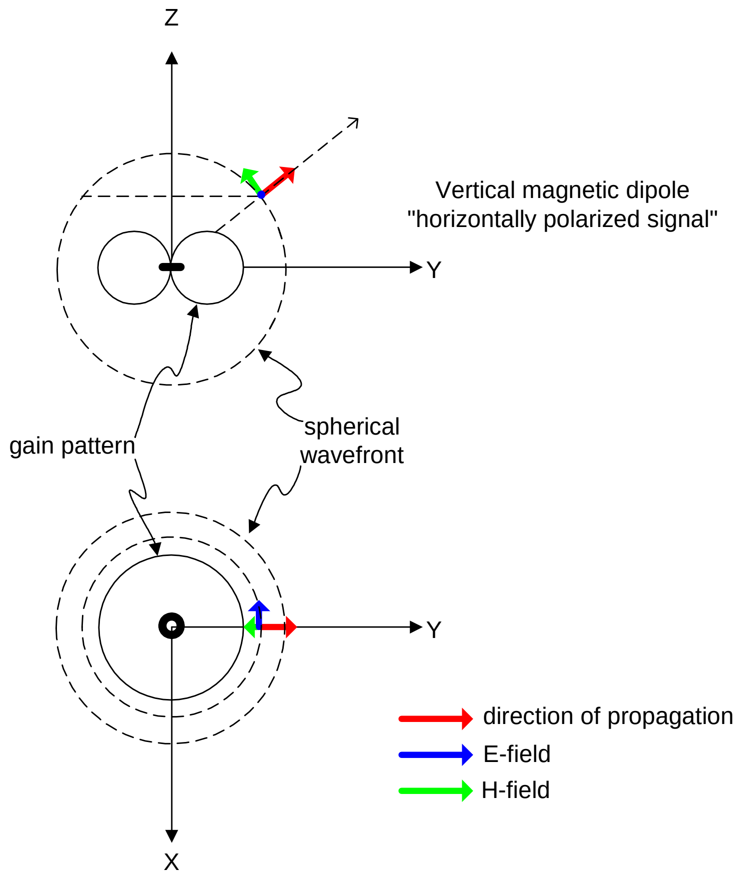


**Figure 10.** E-field and H-field of a magnetic dipole, mounted vertically

Consider once again the two antennas shown in figure 8, but with one of them now a vertically mounted magnetic dipole. It is apparent that the direction of propagation will still be the same, but the E-field of one antenna will be parallel to the H-field of the other. Since the E-field and H-fields are orthogonal, the two antennas will be exactly cross-polarized, regardless of the relative altitudes of the two antennas. Two antennas that are exactly cross-polarized will have infinite isolation, regardless of the relative separation of the two elements (in x, y, and/or z directions). In practice, there will always be a small deviation from perfect 90° alignment of polarizations due to mounting inaccuracies and due to the fact that the curvature of the earth introduces a small change in the definition of "vertically mounted" over practical path distances involved in ATG communications (100 miles represents approximately 1.08° change in "vertical", an amount which will degrade the isolation to 35 dB.)

Note that "stacking" magnetic dipoles will produce a high gain horizontally polarized antenna in the same manner that stacked electric dipoles will produce a high gain vertically polarized signal.

Omnidirectional horizontally polarized antennas, while not in common use in the mobile cellular and PCS bands, are readily available and can be constructed using a variety of techniques. AirCell has in fact used omnidirectional, horizontally polarized antennas on base stations and on aircraft for the last several years in order to maintain isolation between ATG and terrestrial cellular systems.

In summary, we have shown that for a pair of two vertical electric dipole elements, polarization match is maintained regardless of the relative spatial separation of the two elements, even in altitude. Furthermore, we have also shown that for a pair of electric and magnetic dipole elements, polarization isolation is maintained regardless of the relative spatial separation of the two elements, including altitude separation. For such pairs of vertical antenna elements then, the polarization match or the polarization isolation have no dependence on either the altitude of the aircraft or the bearing of the aircraft with respect to the base station for the scenarios of interest. The only deviation is due to small non-vertical orientation errors, as discussed above.

## 5.5. 200 mW mobile transmit power is adequate

AirCell has analyzed the transmit power level needed to provide broadband service, and has concluded that +23 dBm is adequate.

The analysis is based upon a thermal noise floor of –109 dBm, which corresponds to a 1.2288 MHz channel bandwidth with a receiver noise figure of 4 dB. At 75% loading, the maximum noise rise is 6 dB and therefore;

$$I_{tot} = N + (1 + f)\sum_{j=1}^{n} P_j = -109 + 6 = -103dBm \qquad (1)$$

where $I_{tot}$ is the total signal, $N$ is the thermal noise, $f$ is a factor that represents the amount of signals from other cells as a ratio of the in-cell signals, and $\sum_{j=1}^{n} P$ is the total received power from *n* mobile units in the cell.

If there are no signals from mobiles in other cells that reach the receiver, and if there is only a single mobile operating in the cell, then $f = 0$, and (1) reduces to

$$I_{tot} = N + P_1 = -103dBm \qquad (2)$$

where $P_1$ represents the receive power of the single mobile. Since:

$$N = -109dBm \qquad (3)$$

it is apparent that

$$P_1 = -104.3dBm \qquad (4)$$

For a base station receiver designed to operate at 75% of pole point loading, this is the absolute maximum receive signal level from any one mobile. Since there are no other signals considered from mobiles operating on the same cell or nearby cells, this is not a situation that represents a likely design objective. For a slightly more practical (but still very conservative) situation with $f = 0.5$ and two mobiles in the cell ($n = 2$), operating with the same data rate,

$$I_{tot} = N + (1 + 0.5)(2)P_1 = N + 3P_1 \qquad (5)$$

For $I_{tot} = -103dBm$

$$P_1 = -109.1dBm \tag{6}$$

The receive power $P_1$ is a function of the mobile transmit power $T_1$, free space loss $FSL_1$, receive antenna gain $G_R$ and receive cable loss $L_R$

$$P_1 = T_1 - FSL_1 + G_R - L_R \tag{7}$$

An ATG system will require cells roughly 100 miles radius or smaller, in order to provide adequate coverage and capacity to served aircraft. Considering a receive antenna gain of 10 dBi, and cable losses of 3 dB, and

$$FSL_1 = 36.6 + 10(\log 100) + 10(\log 870) = 135.4dB \tag{8}$$

then

$$T_1 = P_1 + 135.4 - 10 + 3 = P_1 + 128.4dBm \tag{9}$$

For the extreme case with a single mobile visible to the cell, the maximum tolerable transmit power would be +24.1 dBm. Increasing the antenna gain, to say +15 dBi, would reduce the maximum transmit power to +19.1 dBm.

Considering the likelihood that network designs will be based upon service to multiple aircraft per cell and some significant level of other-cell interference (requiring that transmit power be reduced several dB further), it is apparent that a maximum mobile transmit power of +23 dBm will be more than adequate to provide broadband service for ATG systems. Telcordia's assertion in [2] that an aircraft EIRP limit of 200 mw is inadequate to support broadband service on the reverse link is clearly not valid.

## 5.6. Path loss margins are not required

In previous papers presented to the FCC as part of Verizon Airfone ex parte submissions, Telcordia allowed a 10 dB margin for link budgets to account for "non-idealities in propagation and implementation, including the effects of multipath and variations in antenna gain due to tolerance in the tilt and horizontal orientation" and "mounting inaccuracy, higher than expected cable loss, fading due to blockage, and other unexpected design losses" [7]. While Telcordia referenced "private communications with Verizon Airfone", neither Telcordia nor Verizon has yet to provide any measurements, other evidence or even rational justification for any of the factors referenced. While AirCell has addressed this in previous filings, it is worth re-iterating some points to help ensure that there is no need to increase mobile transmit powers to overcome fictitious path losses.

An ATG path is essentially a line-of-sight microwave path, and the similar behavior should be anticipated. Considering the rationales listed by Telcordia:

- *multipath* – traditional, well understood microwave path engineering techniques, such as vertical antenna spacing and angular diversity will minimize the effects of both atmospheric multipath and any specular reflections from the ground. Note also that the values of Eb/No used in all

AirCell's analysis include a margin sufficient to account for normal atmospheric multipath.

- *variations in antenna gain due to tolerance in the tilt and horizontal orientation, mounting inaccuracies* – an antenna tilt of 15° would cause a loss of gain of only 0.3 dB - clearly antenna tilt will not be a significant factor. While horizontal orientation impact will depend upon the types of antennas used and the degree of misorientation, misorientation would need to be considerable – a 15° misorientation of one of three 120° antennas has less than a 1 dB impact on the combined pattern created on the reverse link.

- *higher than expected cable losses, fading due to blockage* – such losses would at worst be evident on a very small fraction of all paths (and therefore consistent with "unexpected" design losses. Any paths engineered for blockage will not justify a design margin applied to all paths.)

In [8], Telcordia makes reference to two sets of measurements made by AirCell. In the first, AirCell had provided path loss measurements taken between two aircraft flown with 1000 feet vertical separation and horizontal separations ranging from 0.4 to 5.8 miles (shown below in figure 10). The measurements showed that, with typical air-air path geometries and aircraft separations, air-air isolation levels were adequate to support cross-duplex operations (no longer an issue in this proceeding). The antennas used on the aircraft have a radiation point roughly 8 inches below the fuselage, and the geometry of the fuselage relative to a direct path between two antennas results in various amounts of blockage of the path, depending upon the relative positions of the aircraft, as had been noted by AirCell. Telcordia's representation that these represent "unexpected losses and that it is not unreasonable to expect that similar imperfect link budgets will occur on the air-to-ground link as well" is not in any way justified.

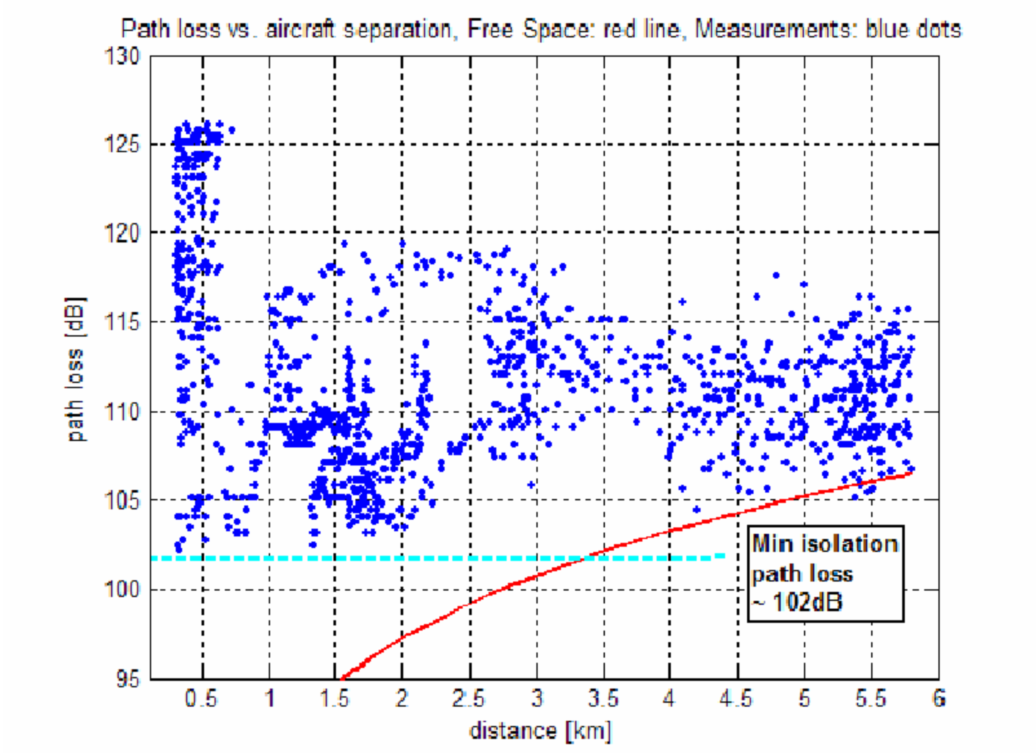


**Figure 10.** Path loss isolation between aircraft, from Figure 1 of [8].

Telcordia, in [8], used flight test data reported by AirCell in [9] to suggest that:

> "AirCell, with its operational experience, surely must understand the magnitude of the variations that can occur on an air to ground link. Figure 2 and Figure 3 show received power vs. distance plots for the air-to-ground link from AirCell's own flight test report [..] (see below). These plots show variations on the order of 10 dB along most of the flight path. It therefore is difficult to understand why AirCell insists that the air-to-ground link will exhibit textbook free-space propagation".

Figure 11 below is one of the figures referenced by Telcordia, and it clearly shows significant variations along the flight path.

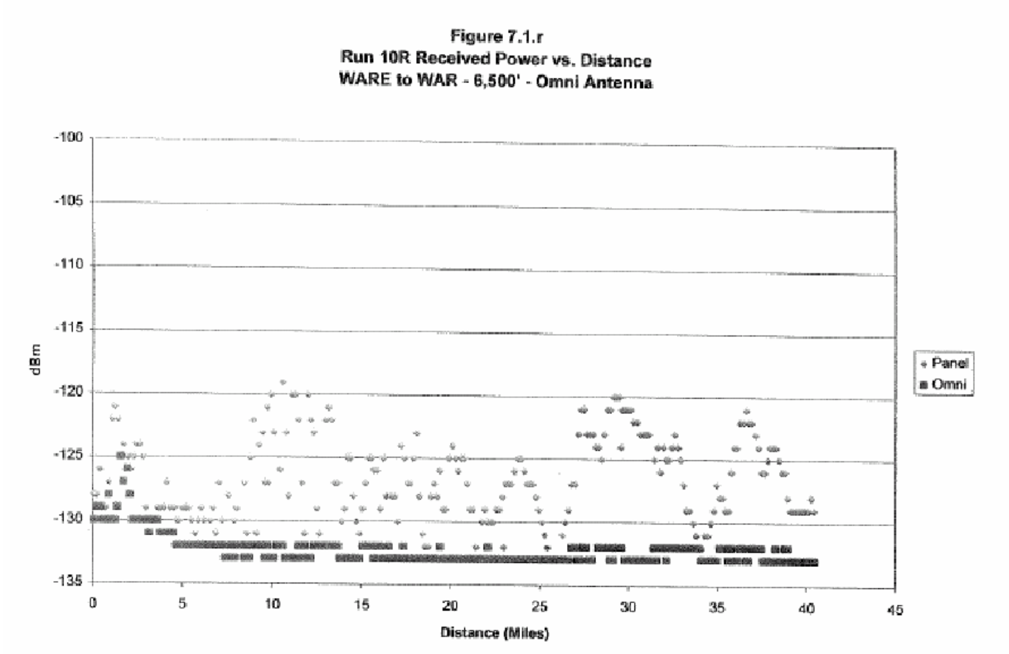


**Figure 11.** Figure 2 from [8]

Figure 4.1 of [9], shown below as Figure 12, shows the flight path on which these signals were recorded. The flight path extends from the location marked WARE to the Waurika 1 (WAR) site. The antenna located at Waurika was a panel antenna, and the system was operated with dynamic power control (DPC) turned on for the duration of the tests.

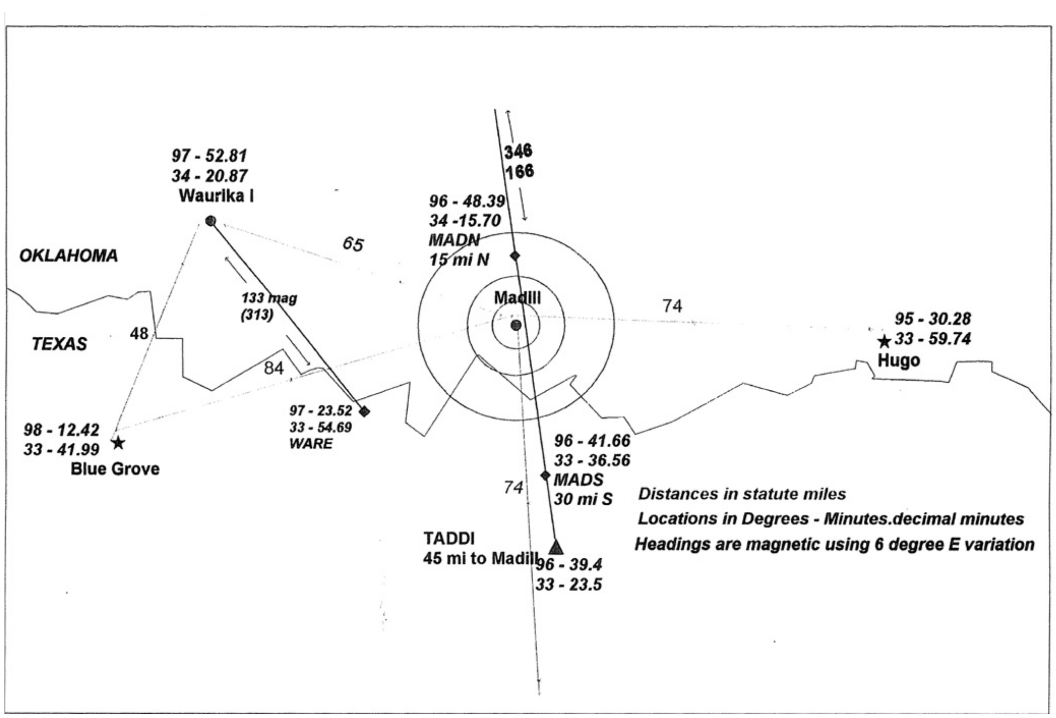


**Figure 12.** Figure 4.1 from AirCell Flight Tests [9]

During this flight test, the Blue Grove site served the aircraft. The mobile transmit power is adjusted by the DPC to maintain a relatively constant receive signal level at the Blue Grove base station. Although the mobile may have some small changes in transmit power due to small changes in the aircraft-Blue Grove path length and small variations in the horizontal pattern of the aircraft test antenna, it may be regarded as relatively constant for the purposes of this discussion.

As the aircraft passes from WARE to WAR, the elevation angle of the aircraft relative to the base station passes from just over 1° to 90°, and the distance changes from 42 miles to 1 mile.

Telcordia has apparently failed to recognize that the expected and predictable changes in the vertical beam patterns of the base antenna and the aircraft antenna are the primary cause of the signal variations. Their apparent belief that this is a signal propagation phenomenon is clearly incorrect.

We also note that when an aircraft is at the edge of a base station's coverage range, both air and ground antennas will both be operating in their main lobes and there will be no comparable signal variations caused by the antenna patterns.

Note as well that these measurements were made on a single antenna; a diversity antenna configuration in an operational system will largely eliminate the angular variations in effective pattern and will also overcome any multipath effects from ground reflections.

In summary, there is no need or justification for a path loss margin such as that indicated by Telcordia, and the transmit power level of +23 dBm will still be adequate.

## 6. Conclusions

The operation of two cross-polarized systems sharing the band as outlined by AirCell and Boeing is entirely feasible. The existence of adequate cross-polarization isolation has been confirmed, and previously submitted performance analysis based upon 12 dB of isolation is conservative based upon recent measurement results.

Significant reductions in interference levels between the ATG band and the adjoining NPSPAC, SMR and Cellular bands will result from the use of terrestrially licensed base stations serving aircraft on the ground, with handoffs to/from ATG-licensed base stations at take-off and landing.

Overall, the proposed approach offers the FCC the opportunity to ensure effective, direct competition for ATG services in US airspace.

## 7. References


[1] Anand Chari, Joe Cruz, Ivica Kostanic, and Grant Saroka, "Deployment of Two Cross Polarized Systems in the ATG Band," AirCell, Inc., October 25, 2004, WT Docket 03-103

[2] Jay Padgett, "Review of AirCell's October 25, 2004 Cross-Polarized ATG Band-Sharing Proposal," November 3, 2004, WT Docket 03-103

[3] Federal Aviation Administration, "Use of Portable Electronic Devices Aboard Aircraft", Advisory Circular 91.21-1A, October 02, 2000

[4] AirCell, Inc., “Providing Deck-to-Deck Coverage,” September 30, 2004, WT Docket 03-1-3

[5] Reply Comments of AirCell, Inc., In the matter of AIRCELL, INC., Petition, Pursuant to Section 7 of the Act, For a Waiver of the Airborne Cellular Rule, Or in the Alternative, For a Declaratory Ruling; AirCell, Inc. Experimental License K12XCS, January 12, 1998,

[6] Ivica Kostanic, “Evolution of the ATG Migration Concept (Part 2),” June 29, 2004, AirCell report to the FCC, WT Docket 03-103

[7] Anthony A. Triolo and Jay E. Padgett, “Coexistence Analysis for multiple Air-to-Ground Systems,” Telcordia Technologies Inc., June 3, 2004, WT Docket 03-103

[8] Jay E. Padgett, “Reply to AirCell September 10, 2004 Response to Telcordia Comments on AirCell Proposals,” Telcordia Technologies, September 24, 2004, WT Docket 03-103

[9] C. J. Hall and I. Kostanic, “Final Report of AirCell Flight Tests,” TEC Cellular, July 10-11, 1997

## Appendix A - Cross-Polarization Discrimination (xpd) Measurements

### Background

In the previous FCC filing [1], AirCell advanced a two-system proposal whereby two systems using different polarizations can share the ATG spectrum. AirCell had stated that 12 dB cross-polarization discrimination is a very conservative value to use for the ATG communications environment when aircraft are flying level.

To determine the cross-polarization discrimination in a typical ATG communications environment, AirCell performed some flight tests. The tests were performed over northern Texas (near Wichita Falls, TX). The tests involved an aircraft equipped with a horizontally-polarized antenna and a base station equipped with a horizontally-polarized (H-pol) and vertically-polarized (V-pol) antenna. The base station antennas were mounted on the same tower at approximately the same heights above ground level.

Figure A1 below represents the test/measurement setup on the aircraft.

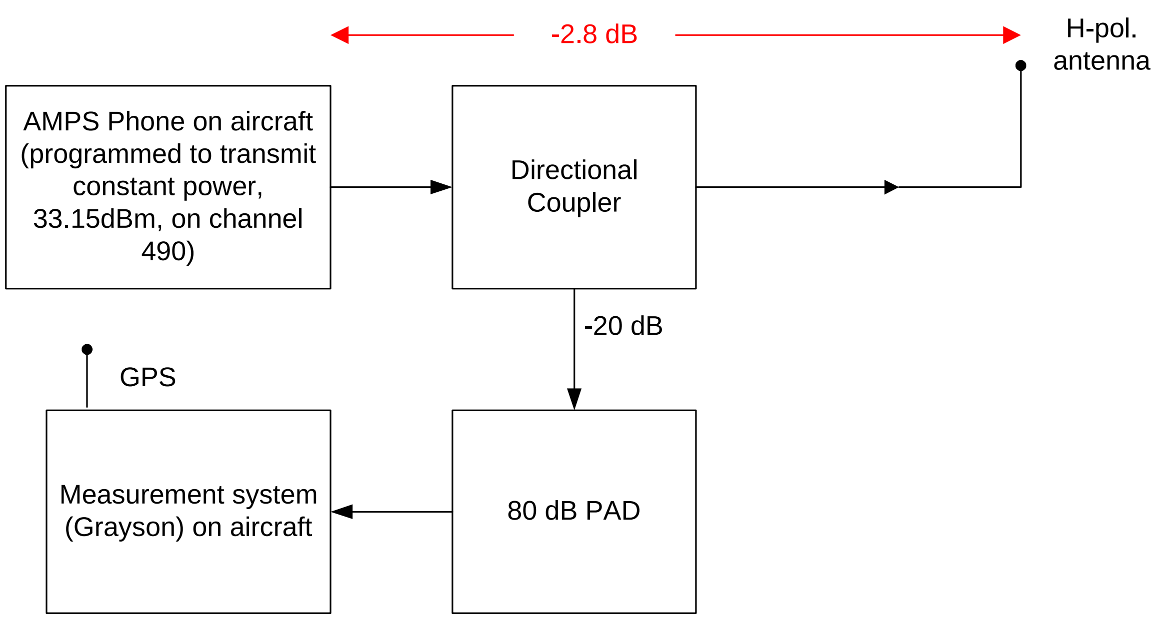


**Figure A1.** Aircraft test/measurement setup

In the aircraft, a source (AMPS phone) was programmed to transmit a constant power signal on an AMPS (analog) channel. This channel was not used anywhere near the base station where the received signal measurements were made. The aircraft was operating the transmitter at fixed transmit power of 33.15 dBm, with 2.8 dB of cable/connector/coupler loss to the antenna input port. The frequency of transmission was set to 839.700 MHz (Cellular band channel 490). The aircraft transmit power and location information were recorded using a Grayson cellular receiver equipment with GPS input on the aircraft.

Figure A2 below represents the test/measurement setup at the base station.

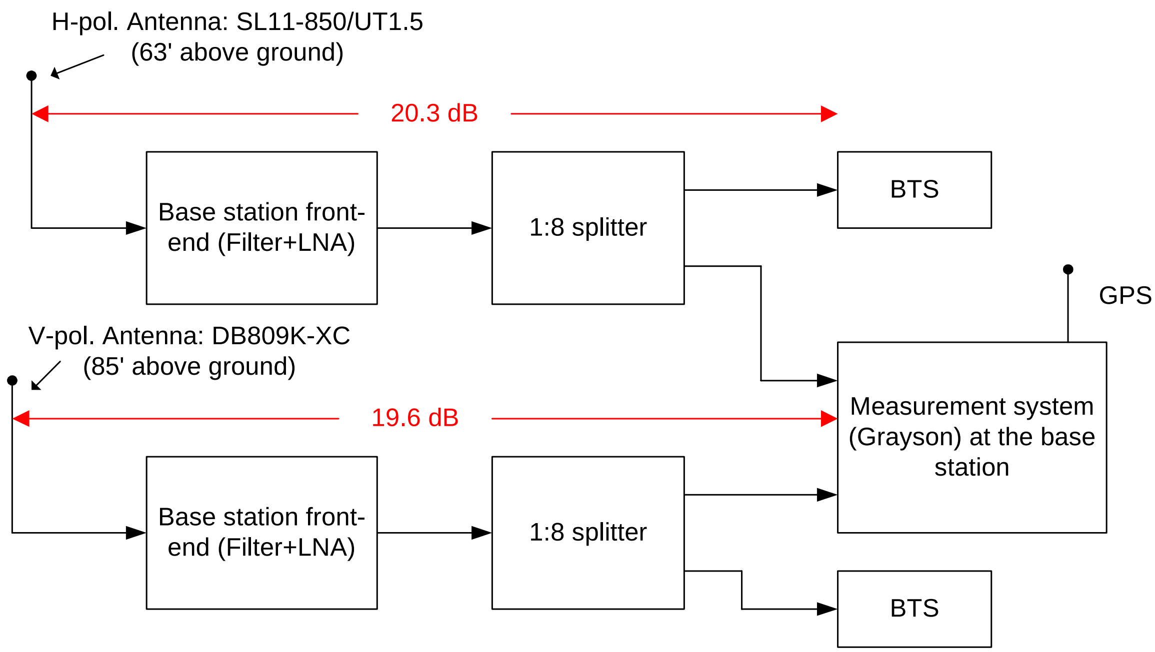


**Figure A2.** Base Station test/measurement setup

At the base station, Grayson cellular receiver equipment was used to record received signal levels from the H-pol and V-pol antenna paths. Measurements were made after the base station front-end (filter + LNA + splitters). The net gains of H-pol and V-pol antenna paths (from antenna to measurement point) were calibrated to compensate for any gain/loss differences.

Figure A3 indicates the flying routes of the aircraft involved in the test.

The aircraft flew at different altitudes and geometry relative to the cell site, however flight test paths were chosen such that the flight was primarily in the main beam of the both base station antennas. The aircraft flight test path included aircraft headings towards and away from the site as well as tangential to a 50-mile and 25-mile radius circles around the cell site.

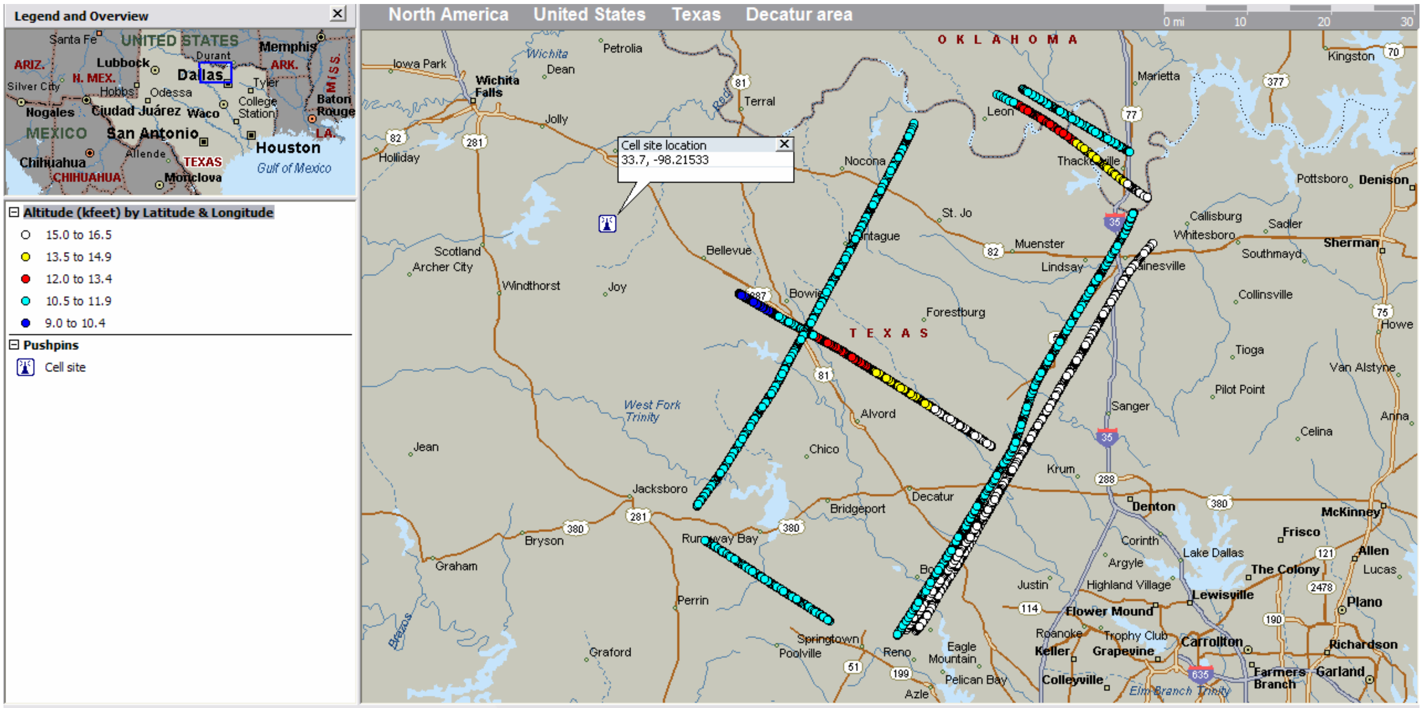


**Figure A3.** Flight route, aircraft altitude for the cross-polarization discrimination test

## Data Processing

Knowing the transmit power from the H-pol antenna aboard the aircraft and measuring the received power using H-pol and V-pol antennas at the base station, AirCell determined the value of cross-polarization discrimination for each measurement point using the following process:

- Aircraft and base station measurements were synchronized using GPS time stamp
- Aircraft position with respect to antennas was determined (azimuth, elevation and distance)
- Antenna pattern gains of the receive antennas in the direction of the aircraft were determined (see Figures A6-A9)
- The measurements were corrected for differences in receive chain gains and antenna pattern gains (reference point is selected before the RX antennas).
- Cross-polarization discrimination (xpd) is determined as the difference between the two corrected signals.
- Measurements considered in the analysis included only those measurement points where a level flight was maintained within in the main beam of the base station antennas, in order to avoid inaccuracies created by pitch/roll of the aircraft and sharp changes in antenna gain near antenna nulls.
- CDF plot, XPD measurement plot and Maps were generated using the processed data.

## Results

Figure A4 provides a map of cross-polarization discrimination observed along the aircraft flight test path. The Cumulative Distribution Function of the cross-polarization discrimination (Xpd) observed is shown in Figure A5. The average value of the xpd is 18.34 dB, and, more than 95% of the time the xpd is greater than 11.5 dB. These results strongly support AirCell's claims about cross-polarization discrimination that can be expected in a typical ATG communications environment.

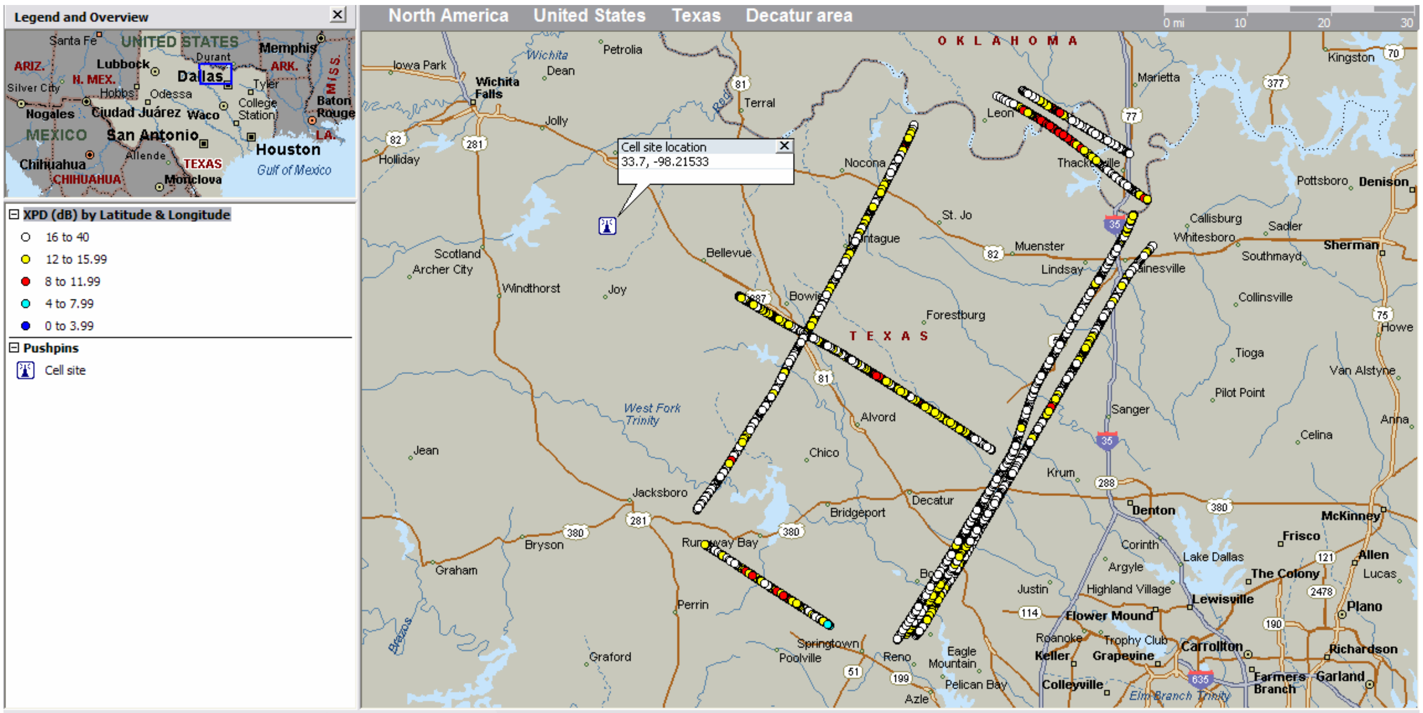


**Figure A4.** Cross-polarization discrimination and aircraft location

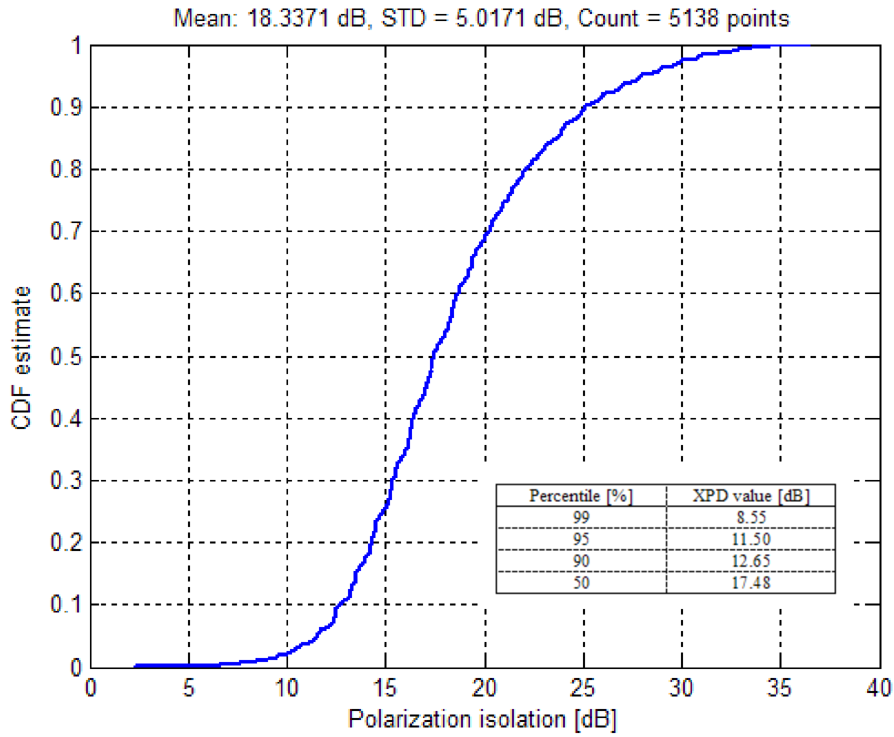


**Figure A5.** CDF for cross-polarization discrimination (xpd)

**Antenna patterns of the base station antennas used in the flight test**

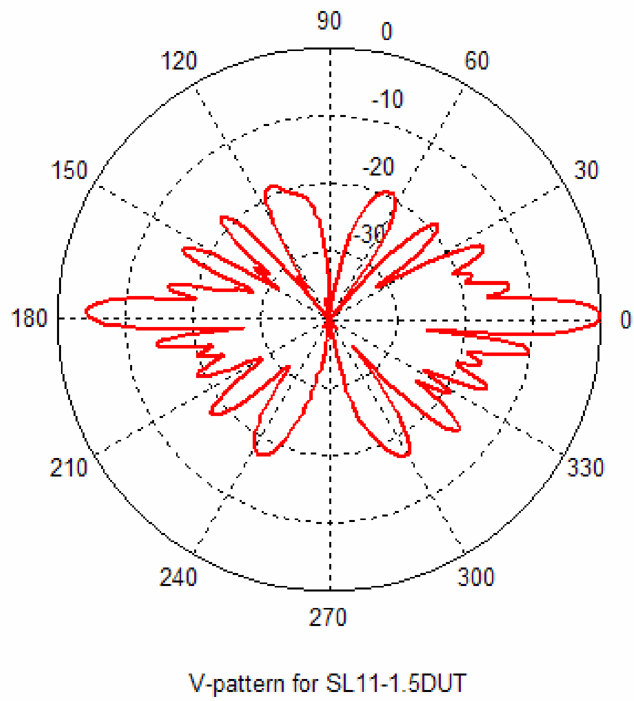


**Figure A6.** H-pol antenna pattern (vertical)

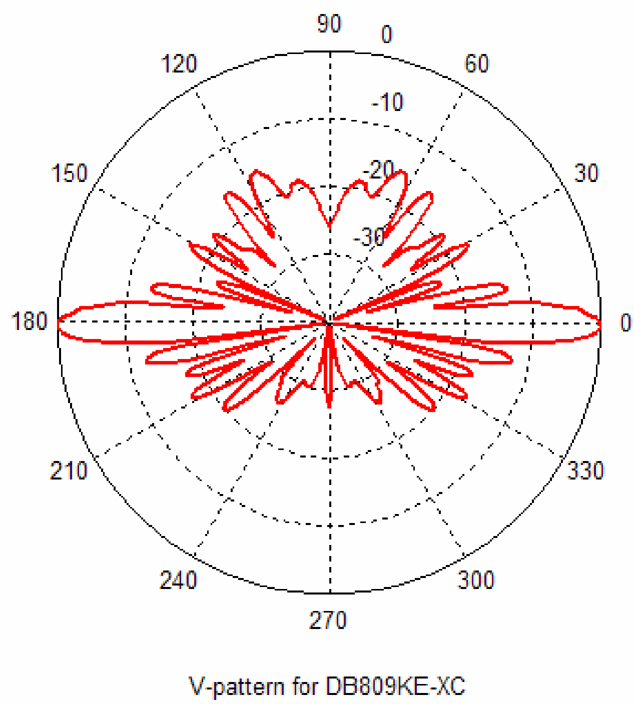


**Figure A7.** V-pol antenna pattern (vertical)

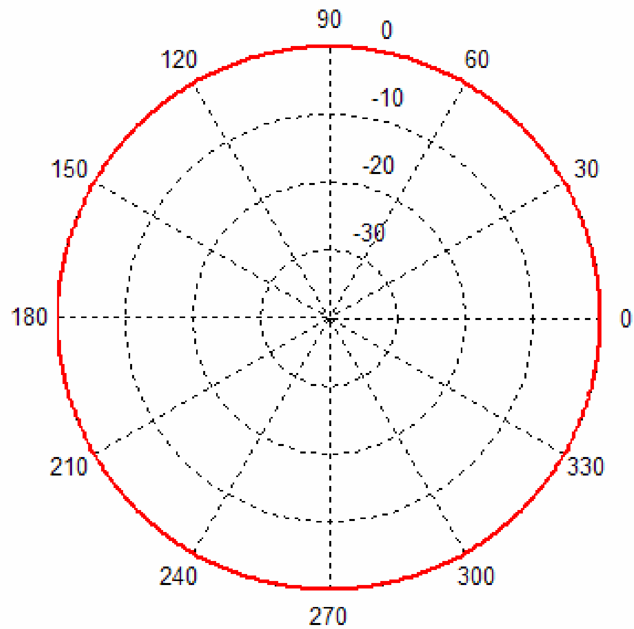


**Figure A8.** V-pol antenna pattern (horizontal)

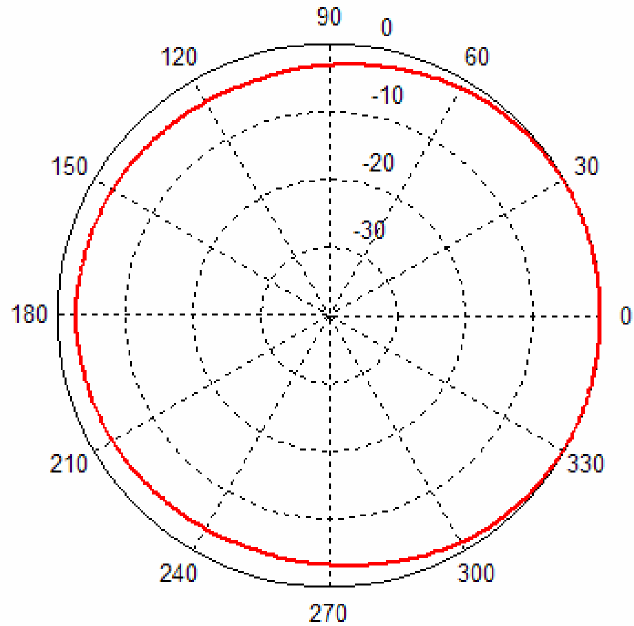


**Figure A9.** H-pol antenna pattern (horizontal)